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ECONOMIC COMPARATIVE ANALYSIS BETWEEN LATTICED UNIDIRECTIONIAL AND PRE-MANUFACTURED SOLID SLABS IN A FOUR-STOREY BUILDING

[1]Nilton Meira Correia Neto and [2]Débora Valim Sinay Neves

[1]Specialist in Management of Engineering Works of Unigrad / BA, Graduated in Civil Engineering by FTC / BA, teacher of FAINOR / BA and FASA / BA, Acting in Civil Engineering courses

[2]PhD in Teaching by - UNIVATES / RS, Master in Teaching of Exact Sciences by - UNIVATES / RS, Specialist in Continuing Education in Media by UESB / BA, Specialist in Innovative Methodologies Applied to Education FACINTER / PR and Bachelor of Laws FAINOR / BA

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ABSTRACT

The article aims at comparative cost analysis between two structural systems in reinforced concrete, one using solid slabs as flat elements and the other using unidirectional prefabricated ribbed slab with lattice beams. For accomplishment of case study, two structural projects of a four-storey building have been elaborated, one project being used solid slab and the other latticed prefabricated slab, taking into account all aspects of structural performance of two types of slab, making the sizing of all structural elements to be built in the most economical way possible, considering NBR 6118/2014, and among those structural elements was disregarded the calculation of foundation, because there is variable factor of soil . The results have been obtained through design of slabs, beams and pillars of the project, and subsequently a quantitative survey of materials and inputs. Through quantitative survey, a budget of two systems has been made based on unit price compositions of SINAPI (National System of Costs Survey and Civil Construction Indexes), as well as unit price references of the same. In that way, it was possible to compare two budgets related to structural systems in reinforced concrete, using solid slabs and unidirectional prefabricated ribbed slabs with lattice beams, reaching the result that differentiates cost between the two systems.

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INTRODUCTION

Civil construction is making a major breakthrough with a growing number of works, contributing to growth of urban centers. With this growth it is important that different construction methods and techniques emerge from conventional ones and those can meet the prospects, as to functionality and performance, providing a lower cost of work. Concerned with economic question of works, engineers, builders and developers have seeked a better solution for their buildings in relation to superstructure, aiming to find the best constructive method and that it provides the lowest possible cost. When executing structures in reinforced concrete, there is the alternative of using different types of slabs, such as solid, ribbed, prefabricated slabs with latticed, pre-stressed joists, among others. In residential buildings of up to four floors the commonly used slabs have been prefabricated slabs with lattice beams and solid slabs. Currently there is still doubt in most of engineering and construction professionals about which method would be most economically viable without losing structural performance of slab, so the problem arises: which constructive method has greater economic viability in residential buildings with four floors, solid slabs or latticed? In that way, the research becomes relevant, as it will provide information needed for engineers and builders regarding the costs of reinforced concrete structures.The construction market is growing dynamically, where the focus has been on meeting deadlines and reducing costs, with projects designed in the best way which meet the needs of users. However, it is possible to notice the indecision of professionals and builders when choosing the best structural system due to lack of precise parameters which can guide them in that choice.

****Corresponding author:*NiltonMeiraCorreiaNeto**
Specialist in Management of Engineering Works of Unigrad / BA, Graduated in Civil Engineering by FTC / BA, teacher of FAINOR / BA and FASA / BA, acting in Civil Engineering courses.

This research has the objective of performing a comparative analysis regarding economic aspects in use of solid slabs in reinforced concrete and prefabricated lattice slabs. For that, a structural concrete project was elaborated of a residential building of 04 floors. Subsequently, a quantification of materials necessary for execution of structure was carried out. Two budgets of structure were elaborated, one of them was used solid slab in reinforced concrete and the other, prefabricated lattice slab, and a comparative analysis of the two budgets has been made in order to find out which construction system would be most feasible for residential buildings of 4 floors. In that way, the research has defined statistical parameters of costs in relation to structural systems in reinforced concrete that will help engineers and builders in choice of type of slab to be used in their works.

Theoretical background

Structure and structural elements: According to Pinheiro (2010), structure is all resistant part of the building, and has as function the support of loads and actions, making the transmission of these to the ground. Structures of buildings are constituted by structural elements, the main ones are: I) Slabs - can be called surface elements, flat elements, or plates (BASTOS, 2013). I) According to NBR 6118/2014, plates are flat surface elements, subject to normal actions to their plane.Pinheiro (2010) states that besides the permanent loads, slabs receive the actions of use of structure and transmit to its supports; II) Beams - "They are horizontal bars that delimit slabs, support walls and receive actions from slabs or other beams and transmit them to supports" (PINHEIRO, 2010, p.7). According to NBR 6118/2014, beams are linear structural elements, where bending is preponderant; III) Pillars - "They are bars that receive the actions of beams or slabs and upper floors transmit them to lower elements or to foundation" (PINHEIRO, 2010, p.8). According to NBR 6118/2014, pillars are linear structural elements of straight axis, generally arranged vertically, where compression effort is preponderant.

Reinforced concrete: According to Carvalho and Figueiredo Filho (2013, p.19), reinforced concrete can be "obtained through association between simple concrete and suitably placed reinforcement (passive reinforcement), in such a way that both resist jointly the applicant efforts." "Botelho and Marchetti (2013, p.27) state that" an reinforced concrete structure is a solid bond of concrete with a tensile structure, which is usually steel. Confirming the aforementioned authors, NBR 6118/2014 (p.3) points out that the elements of reinforced concrete are "those whose structural behavior depends on adhesion between concrete and reinforcement."

Structural analysis

The objective of structural analysis is to determine the effects of the actions in a structure, in order to carry out final state (ELU) and service (ELS) checks. The structural analysis allows to establish distributions of internal stresses, tensions, deformations and displacements, in one part or in whole structure (NBR 6118/2014, p.81).In that bias, Bastos (2011) states that the security which all types of structures must present involve two aspects. The first is that structure should not get to rupture; the second is related to comfort, tranquility, appearance and use of construction. NBR 6118/2014 refers to those two aspects as "Limit States", which are limiting situations that the structure should not exceed. The boundary state related to collapse of structure is called "Last Limit State" and the user's security in using the structure is called "Service Limit States."

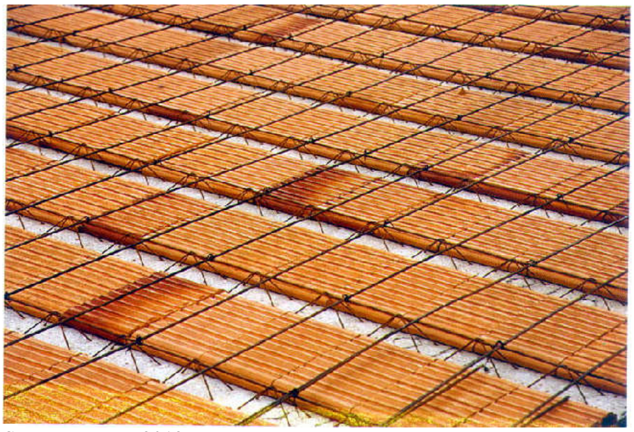
Structural design

The choice of structure for residential and commercial buildings depends on essentially economic factors, since technical conditions to develop structural design and conditions for construction are knowledge of structure and construction engineering (GIONGO, 2007, p. 1). The calculations of stresses acting on a structure can be made in a simplified way, separating structural elements and calculating each of them separately, or can be done in a more elaborate way, which is considering set of beams and slabs as grids and set beams and pillars as a space gantry (GIONGO, 2007).Simplified calculation process is accepted by national standards, but computational process must be done by computational software of structural calculation. Structural design must have positioned structural elements, slabs, beams and pillars, according to architectural design (GIONGO, 2007). The author still states that the provision "of structural elements must meet particular conditions of architectural arrangement and structural safety conditions of the building" (p.18).

Solid slabs: Solid slab can be described as all that in its entire thickness is composed of concrete, containing longitudinal flexural reinforcement, supported on beams or walls (BASTOS, 2013). The above-mentioned author states that massive slabs can be designed for the most varied types of constructions, such as residential or multi-storeycommercial buildings. Still according to the author, usually that type of slab is not applied for residential or commercial buildings of small size, because in those cases prefabricated ribbed slabs have advantages in cost and easiness of execution. According to Pinheiro (2010), in usual buildings, massive slabs contribute around 50% in concrete consumption of structure. In bridges and multi-storey buildings, or in large constructions, massive slabs are more common among different types of existing slabs (BASTOS, 2013).

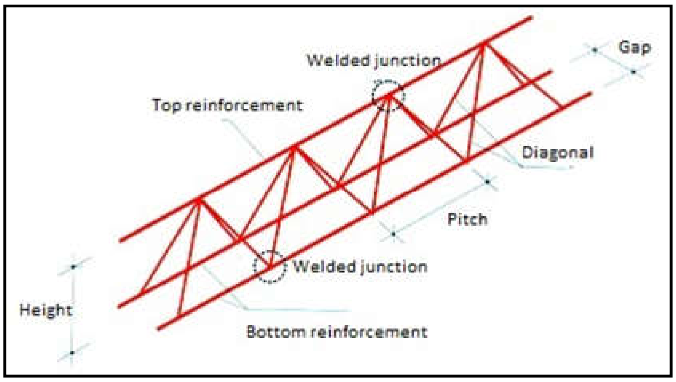
Pre-cast slabs with lattice beams

Slab that has its constituent parts manufactured on an industrial scale at a factory site may be reinforced concrete or pre-stressed concrete. They are applied in both small and large buildings (BASTOS, 2013, p.83). Pre-cast slabs with lattice beams are also classified as ribbed slabs. Ribbed slabs are the molded slabs on the site or with pre-shaped ribs, which traction zone for positive moments is located in ribs between which inert material may be placed. (NBR 6118/2014, p.97). Ribbed slabs with latticed beams, according to Figure 2, are also called by Bastos (2013) a "prefabricated unidirectional slab", where the same author describes these as "slabs consisting of longitudinal main ribs, disposed in a single direction" (p.83).Latticed slabs consist of ribs, which can also be called beams, concrete and reinforcement, filling blocks and a concrete capping at the top (BASTOS, 2013) According to Carvalho and Figueiredo Filho (2013, p.64) , the armor of joist "is a steel space lattice composed of three parallel and diagonal lateral flanges of sinusoidal form, welded by electronic process to flanges". The geometry of the lattice reinforcement can be seen in Figure 2:



Source: Bastos, 2013

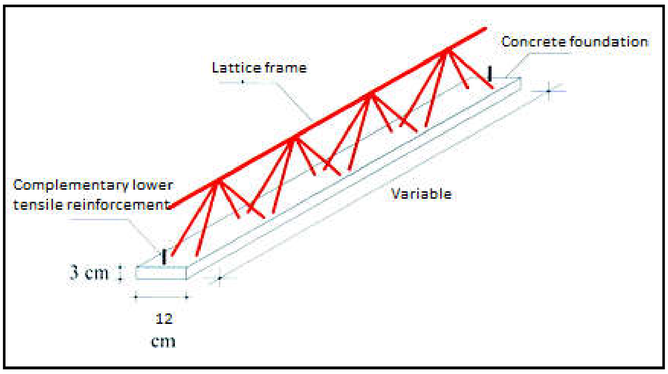
Figure 1. Prefabricated slab with lattice beams



Source: Bastos, 2013

Figure 2. Space lattice

Carvalho and Figueiredo Filho (2013) state that in the assembly and concreting phases, precast elements are the resistant ones, that can resist beyond their own weight, the action of tiles, concrete of cover and a small accidental load of a man moving for spans up to 1,5m. The joist formed by steel lattice and pre-cast element can be identified in Figure 3:



Source: Bastos, 2013

Figure 3. Pre-cast lattice joist

The main advantage of that type of slab is which it is not necessary to use formwork, since filler element and precast composite already play this role, enabling the concreting of concrete cover without use of formwork (CARVALHO E FIGUEIREDO FILHO , 2013). Filler elements in addition to shape function, giving necessary geometry for the ribs, also provide smooth lower surfaces. Preferably these elements should be light and lower cost, the most used materials being ceramic tiles, cellular concrete or EPS. NBR 14859-1 / 2002, it allows a complementary longitudinal reinforcement, a distribution armor in concrete cover in transverse and longitudinal directions, to distribute actions of concentrated loads and to control cracking, must also be arranged.

Budget: According to(1989, p.17) apud (SANTOS *et al*., 2012, page 211), "Budget is the calculation of costs to execute a work or an enterprise. The more detailed, the closer it will be to real cost. "When elaborated, a budget must contain all services to be executed in the work, including physical quantitative survey of project and composition of unit costs of each service, social laws and complementary charges (TISAKA, 2011, apud SANTOS *et al*).The cost of a reinforced concrete structure cast in loco, considering conventional buildings, results in order of 20% to 25% of total cost of work (GIONGO, 2007).In a reinforced concrete structure we can divide the cost into items that make up the structure, such as concrete, steel, and other costs that may affect the structure. According to Giongo (2007), these costs may have an estimated division as shown in Table 1 below:

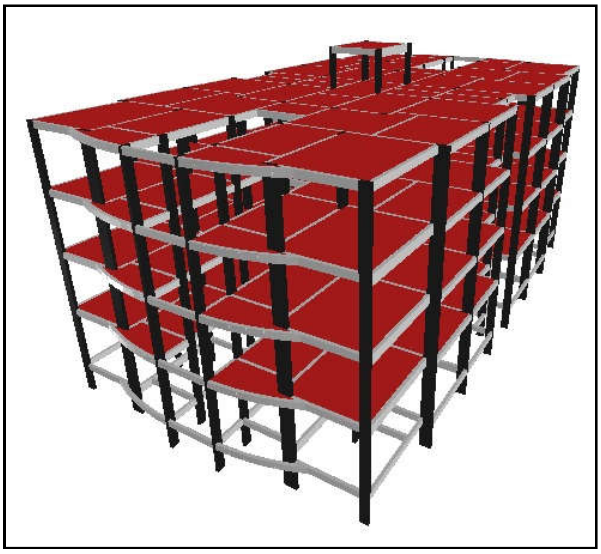
Table 1. Partial costs in total structure

Structure composition items	*Equivalent cost*
Concrete	24,08%
Steel	27,87%
Mold	42,34%
Scaffolding	0,56%
Launch and application of concrete	5,16%
Total	100%

Search: Giongo, 2007

MATERIALS AND METHODS

This work is a quantitative research and, according to the objectives, is classified as exploratory, since there is still little knowledge about and there are not many published bibliographies on this subject. In order to do so, a literature review was carried out based on literary materials, scientific articles and lecture notes from professors and authors recognized in academic field in the area of civil engineering. Those have provided an effective basis for delineation of investigative activity proposed here. With regard to technical procedures, this is a case study, carried out by means of a structural design in reinforced concrete, using two different types of slabs, solid slabs and prefabricated lattice slabs, without altering the structural design of project, only with alteration of dimensions of structural elements seeking the maximum economic efficiency without losing their structural performance, respecting the Brazilian technical standards, being the most used to NBR 6118/2014 - Concrete Structures Project - Procedure. The requirements of NBR 6118/2014 were complied with regarding the dimensioning of elements in relation to Ultimate Limit State and Service Limit States, aiming at maintaining the resistive capacity of structural elements as well as maintaining the values of displacements below the prescribed criterion in the same standard and maintain those values with little variation in two executive methods that will be applied to slabs of that building. Through this research it was possible to carry out the quantitative survey of materials and labor required for execution of two types of constructive method. From quantitative ones, two budgets were elaborated through composition of services, and prices of inputs and services were obtained through SINAPI - National System of Research of Costs and Indexes of Civil Construction. After elaboration of budgets, a comparison was made between two systems through tables and graphs that represent the economic viability of construction systems, and



Source: Project data (2015)

Figure 4. Space gantry

Table 2. Composition of unit cost of Formworks

Code	*Description*				*Unit*
84216	FORMWORK FOR CONCRETE STRUCTURES (PILLAR, BEAM AND SLAB) IN RESINED COMPENSATED WOODEN PLATE, OF 1,10X 2,20, THICKNESS = 12 SQM, 05 USES: (MANUFACTURE, ASSEMBLY AND DISASSEMBLY)				M²
Code	**Material**	**Unit**	**Quant.**	**Unit price**	**Total price**
1357	COMPENSATED WOODEN PLATE RESINED CONCRETE, OF * 2,2 X 1,1 * M, E = 12 SQM	UN	0,1140	R$ 34,07	R$ 3,88
2692	PROTECTIVE DEMOLDING FOR WOOD FORMWORKS, OIL-BASE EMULSED IN WATER.	L	0,0060	R$ 4,42	R$ 0,03
4491	NATIVE / REGIONAL WOODEN PIECE 7.5 X 7,5CM (3X3) NOT MACHINED (TO FORMWORK)	M	0,6800	R$ 5,51	R$ 3,75
4506	IN DEACTIVATION PROCESS! NATIVE / REGIONAL WOODEN PECE 2.5 X 10 CM (1X4 ") NOT MACHINED (FILLET-TO FORMWORK)	M	0,3600	R$ 3,42	R$ 1,23
5068	NAIL POLISHED WITH HEAD 17 X 21	KG	0,2600	R$ 8,40	R$ 2,18
6189	WOOD BOARD 2A QUALITY 2.5 X 30.0CM (1 X 12 ") NOT MACHINED	M	0,2000	R$ 17,28	R$ 3,46
Item	**Labor**	**Unit**	**Quant.**	**Unit price**	**Total price**
1	CARPENTER ASSISTANT WITH COMPLEMENTARY CHARGES	H	0,1900	R$ 9,00	R$ 1,71
2	CARPENTER OF FORMWORKS WITH COMPLEMENTARY CHARGES	H	0,7500	R$ 11,99	R$ 8,99
				Subtotal	R$ 10,70
Social charges				**Social charges**	R$ 12,84
				Total 2	R$ 23,55
Item	**Equipment**	**Unit**	**Quant.**	**Unit price.**	**Total price**
					0,00
				Total 3	0,00
				Grand total	R$ 38,07

can thus reach a conclusion based on data that could generate precise parameters regarding the economic viability of massive slabs and lattice prefabricated slabs.

RESULTS AND DISCUSSION

Characterization of the enterprise: The structural projects that have been elaborated are reinforced concrete structures with the purpose of stabilizing and absorbing efforts from loads in a residential building with four floors. The building consists of 16 residential units of 98.62sqm, four units per floor, the built area of each floor is 442,22sqm, the total area of the development of 1768.88sqm. Each apartment has three bedrooms, one of them is a suite, a living and dining room, kitchen, service area and bathroom.

Structural design

The structural design of the building was planned and designed so that the structure worked as a space gantry formed by slabs, beams and pillars. The slabs, responsible for receiving loads of their own weight, lower coating, subfloor, floor and variable loads of use of building. The beams, acting to resist the loads transmitted by slabs or loads of other beams that support them, as well as loads coming from the walls of brickwork. The pillars have the function of supporting beams and transmitting loads to foundation, thus constituting a monolithic gantry. Figure 5 expresses the structural design of the space gantry.

Standardization

The project followed the Brazilian standards for structural reinforced concrete projects, NBR 6118/2014, complying with requirements for minimum sections of concrete, minimum and maximum sections of steel, as well as verification of structure in relation to States Limits of Service and Last State Limit. The loads considered in dimensioning of structural elements were considered according to NBR 6120/1980, both permanent loads, as well as variable loads.

Table 3. Composition of unit cost of CA-50 Steel

Code	*Description*				*Unit*
74254/002	CA-50 STEEL FRAME, DIAM.6,3 (1/4) TO 12.5SQM (1/2) - SUPPLY / CUT (LOSS OF 10%) / DOUBLE / PLACEMENT				KG
Code	Material	Unit	Quant.	Unit price	Total price
34	CA-50 STEEL, 10,0SQM, REBAR	KG	1,1000	R$ 3,65	R$ 4,02
337	ANNEALED WIRE 18 BWG, 1,25SQM (0,01 KG/M)	KG	0,0300	R$ 9,00	R$ 0,27
				Total 1	R$ 4,29
Item	Labor	Unit	Quant.	Unit price	Total price
1	ASSEMBLER ASSISTANT WITH COMPLEMENTARY CHARGES	H	0,1000	R$ 9,00	R$ 0,90
2	ASSEMBLER WITH COMPLEMENTARY CHARGES	H	0,1000	R$ 11,99	R$ 1,20
				Subtotal	R$ 2,10
Social charges				Soc. charges	R$ 2,52
				Total 2	R$ 4,62
Item	Equipment	Unit	Quant.	Unit price	Total price
					0,00
				Total 3	0,00
				Grand total	R$ 8,90

Source: SINAPI (2015)

Table 4. Composition of unit cost of CA-60 Steel

Code	*Description*				*Unit*
73942/002	CA-60 STEEL FRAME, DIAM. 3,4 A 6.0SQM-SUPPLY / CUT (W / 10% LOSS) DOUBLE / PLACEMENT				KG
Code	Material	Unit	Quant.	Unit price	Total price
39	STEEL CA-60, 5,0 SQM, REBAR.	KG	1,1000	R$ 3,61	R$ 3,97
337	ANNEALED WIRE 18 BWG, 1,25 MM (0,01 KG/M)	KG	0,0200	R$ 9,00	R$ 0,18
				Total 1	R$ 4,15
Item	Labor	Unit	Quant.	Unit price	Total price
1	ASSEMBLER WITH COMPLEMENTARY CHARGES	H	0,1000	R$ 11,99	R$ 1,20
2	ASSEMBLER´S MATE WITH COMPLEMENTARY CHARGES	H	0,1000	R$ 9,00	R$ 0,90
				Subtotal	R$ 2,10
Social charges				Soc. charges	R$ 2,52
				Total 2	R$ 4,62
Item	Equipment	Unit	Quant.	Unit price	Total price
					0,00
				Total 3	0,00
				Grand total	R$ 8,77

Source: SINAPI (2015)

Table 5. Composition of unit cost of 25 MPa Machined Concrete

Code	*Description*				*Unit*
74138/003	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.				M³
Code	Material	Unit	Quant.	Unit price	Total price
1527	MACHINED CONCRETE PUMP, RESISTANCE CLASS C25, WITH GRAVEL 0 AND 1, SLUMP = 100 +/- 20 SQM, INCLUDES PUMPING SERVICE (NBR 8953)	M³	1,0500	R$ 302,21	R$ 317,32
				Total 1	R$ 317,32
Item	Labor	Unit	Quant.	Unit price	Total price
1	ASSEMBLER WITH COMPLEMENTARY CHARGES	H	0,6000	R$ 11,99	R$ 7,19
2	CARPENTER OF FORMWORKS WITH COMPLEMENTARY CHARGES	H	0,6000	R$ 11,99	R$ 7,19
3	BRICKLAYER WITH COMPLEMENTARY CHARGES	H	0,6000	R$ 11,99	R$ 7,19
4	BRICKLAYERS'S MATE WITH COMPLEMENTARY CHARGES	H	1,6000	R$ 7,08	R$ 11,33
				Subtotal	R$ 32,91
Social Charges				Soc. charges	R$ 39,49
				Total 2	R$ 72,40
Item	Equipment	Unit	Quant.	Unit price	Total price
10485	IMMERSION VIBRATOR WITH ELECTRIC MOTOR 2HP MONO-PHASIC ANY DIAM W / HOSE	H	0,3000	R$ 0,75	R$ 0,23
				Total 3	R$ 0,23
				Grand total	R$ 389,95

Source: SINAPI (2015)

Budgeting: A quantitative survey was made of materials and services required to carry out the structure in reinforced concrete. The quantitative survey, multiplied by unit prices of each service, will result in that budget. In each service a unit price composition was made, according to units of specific measures of each one, through SINAPI (2015) analytical composition worksheet. Compositions of unit prices, size the quantity of inputs and labor employed in each service, thus also costs with social charges are calculated.

According to Composition of Social Charges of SINAPI (2015), for the month 04/2015, for the state of Bahia, social costs of hourly workers for calculation without exoneration are of order of 120.02%. The following tables show how unit prices were obtained through SINAPI analytical price unit worksheets (08/2015). Table 2 refers to composition of unit costs of molds that will be used for molding of beams, pillars and solid slabs. Table 3 refers to unit cost composition of CA-50 steel used in composition of reinforcement for columns, beams and slabs.

Table 6. Composition of unit cost of precast slab

Code	Description				Unit
74141/001	PRECAST SLAB BETA 16 P / 3,5KN / M2 SPAN 5,2M INCL BRICK JOISTS NEGATIVE REINF CAPACITY 3 CM CONCRETE 15MPA SHORING MATERIAL AND LABOR.				M²
Code	Material	Unit	Quant.	Unit price	Total price
3739	PRECAST SLAB OF CONVENTIONAL FLOOR OVERLOAD 200 KG / M2 SPAN TILL 5,00M	M2	1,0000	R$ 32,99	R$ 32,99
4491	NATIVE / REGIONAL WOODEN PIECE 7.5 X 7,5CM (3X3) NOT MACHINED (TO / FORMWORK)	M	1,1000	R$ 5,51	R$ 6,06
5075	NAIL POLISHED WITH HEAD 18 X 30	KG	0,0200	R$ 7,95	R$ 0,16
6189	WOOD BOARD 2A QUALITY 2,5 X 30,0CM (1 X 12") NOT MACHINED	M	0,3000	R$ 17,28	R$ 5,18
				Total 1	R$ 44,39
Item	Labor	Unit	Quant.	Unit price	Total price
1	CARPENTER OF FORMWORKS WITH COMPLEMENTARY CHARGES	H	0,2500	R$ 11,99	R$ 3,00
2	BRICKLAYER WITH COMPLEMENTARY CHARGES	H	0,4000	R$ 11,99	R$ 4,80
3	BRICKLAYERS'S MATE WITH COMPL. CHARGES.	H	0,9000	R$ 7,08	R$ 6,37
				Subtotal	R$ 14,17
Social charges				Soc. charges	R$ 17,00
				Total 2	R$ 31,16
Item	Equipment	Unit	Quant.	Unit price	Total price
					0,00
				Total 3	0,00
				Grand Total	R$ 75,56

Source: SINAPI (2015)

Tabela 7. OrçamentoAnalíticoparalajesmaciças

ITEM	*Code*	*Source*	*DESCRIPTION*	*UNIT*	*QT.*	*UNIT PRICE*	*PRICE*
1.0			SUPERSTRUCTURE				
1.1			PILLARS				R$ 114.911,08
1.1.1	84216	Sinapi	FORMWORK FOR CONCRETE STRUCTURES (PILAR, BEAM AND SLAB) IN RESINED COMPENSATED WOODEN PLATE, OF 1,10X 2,20, THICKNESS = 12SQM, 05 USES. (MANUFACTURE, ASSEMBLY AND DISASSEMBLY)	M²	905,91	R$ 38,07	R$ 34.491,62
1.1.2	74254/002	Sinapi	STEEL FRAME CA-50, DIAM. 6,3 (1/4) TO 12.5SQM (1/2) SUPPLY/ CUT (LOSS OF 10%) / FOLD / PLACEMENT	KG	5119	R$ 8,90	R$ 45.573,43
1.1.3	73942/002	Sinapi	STEEL FRAME CA-60 DIAM. 3,4 A 6,0SQM-SUPPLY / CUT (LOSS OF 10%) FOLD / PLACEMENT	KG	1685	R$ 8,77	R$ 14.775,43
1.1.4	74138/003	Sinapi	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.	M³	51,47	R$ 389,95	R$ 20.070,60
1.2			BEAMS				R$ 139.611,35
1.2.1	84216	Sinapi	FORMWORK FOR CONCRETE STRUCTURES (PILAR, BEAM AND SLAB) IN RESINED COMPENSATED WOODEN PLATE, OF 1,10X 2,20, THICKNESS = 12SQM, 05USES. (MANUFACTURE, ASSEMBLY AND DISASSEMBLY)	M²	1392,11	R$ 38,07	R$ 53.003,20
1.2.2	74254/002	Sinapi	STEEL FRAME CA-50, DIAM. 6,3 (1/4) TO 12.5SQM (1/2) - SUPPLY / CUT (LOSS OF 10%) / FOLD / PLACEMENT	KG	4742,7	R$ 8,90	R$ 42.223,31
1.2.3	73942/002	Sinapi	STEEL FRAME CA-60 DIAM. 3,4 TO 6,0 SQM - SUPPLY / CUT (W/ LOSS OF 10%) FOLD / PLACEMENT	KG	1293,3	R$ 8,77	R$ 11.340,69
1.2.4	74138/003	Sinapi	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.	M³	84,74	R$ 389,95	R$ 33.044,15
1.3			SLABS				R$ 209.097,19
1.3.1	84216	Sinapi	FORMWORK FOR CONCRETE STRUCTURES (PILAR, BEAM AND SLAB) IN RESINED COMPENSATED WOODEN PLATE, OF 1,10X 2,20, THICKNESS = 12SQM, 05USES. (MANUFACTURE, ASSEMBLY AND DISASSEMBLY).	M²	1556,79	R$ 38,07	R$ 59.273,22
1.3.2	74254/002	Sinapi	STEEL FRAME CA-50, DIAM. 6,3 (1/4) TO 12.5SQM (1/2) SUPPLY / CUT (LOSS OF 10%) / FOLD / PLACEMENT	KG	6861,4	R$ 8,90	R$ 61.085,67
1.3.3	73942/002	Sinapi	STEEL FRAME CA-60 DIAM. 3,4 A 6.0SQM-SUPPLY / CUT (LOSS OF 10%) FOLD / PLACEMENT	KG	3713	R$ 8,77	R$ 32.558,55
1.3.4	74138/003	Sinapi	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.	M³	144,07	R$ 389,95	R$ 56.179,74
TOTAL							R$ 463.619,61

Source: Research data (2015)

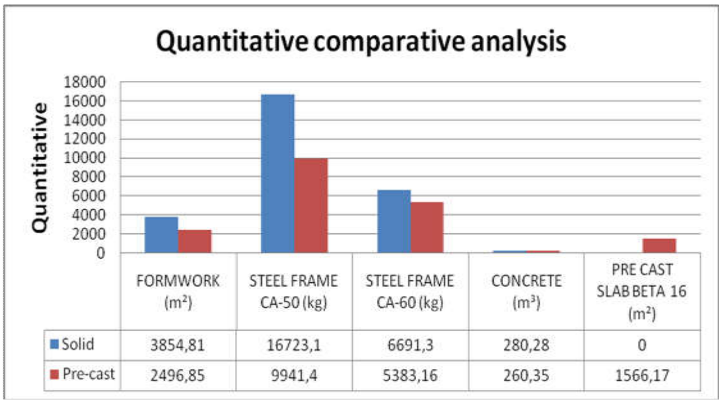
Table 4 refers to unit cost composition of CA-600 steel used in composition of frames for stirrups of pillars and beams, as well as in frames of bending and distribution of solid and preformed slabs. Table 5 refers to composition of unit costs of machined concrete with compressive strength of 25 MPa, which is used in composition of all structural elements in reinforced concrete. Table 6 refers to composition of unit costs of preformed slab beta 16, which is used in composition of unidirectional ribbed slabs with lattice beams. For the budget, the stages for execution of slabs, beams and pillars were divided, and for each structural element there were subdivisions referring to concrete, forms and reinforcement, according to Tables 7 and 8, as follows:

Table 7 shows the budget of structure under analysis using solid slabs, where the total value of four hundred sixty-three thousand, six hundred and nineteen reals and sixty-one cents (R$ 463,619.61) was obtained. Table 8 expresses the budget of structure under analysis using pre-cast slabs with unidirectional lattices, in which the total value of four hundred and fifty thousand, six hundred and thirty-four reals and eighty-eight cents (R$ 450,634.88) was obtained. It is possible to make a comparative analysis of input quantities of two structures through Figure 6.It was possible to analyze that structural system with massive slabs has obtained a greater consumption in formworks, steel and concrete, but in structural system with precast slabs the consumptions with steel CA-60

Table 8. Analytical budget for preformed slabs

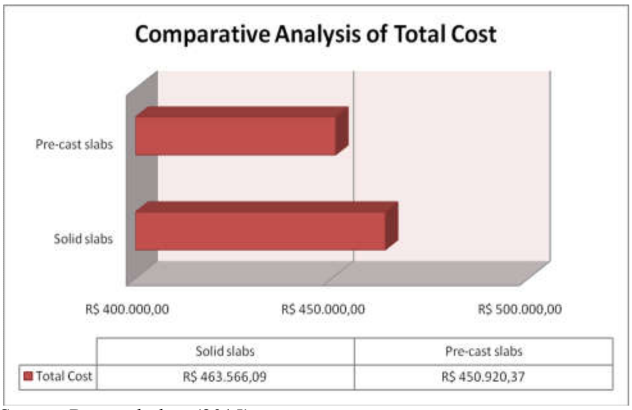
ITEM	Code	Source	DESCRIPTION	UNIT	QT.	UNIT PRICE	PRICE
1.0			SUPERSTRUCTURE				
1.1			PILLARS				R$ 112.453,58
1.1.1	84216	Sinapi	FORMWORK FOR CONCRETE STRUCTURES (PILAR, BEAM AND SLAB) IN RESINED COMPENSATED WOODEN PLATE, OF 1,10X 2,20, THICKNESS = 12SQM, 05USES. (MANUFACTURE, ASSEMBLY AND DISASSEMBLY)	M²	905,91	R$ 38,07	R$ 34.491,62
1.1.2	74254/002	Sinapi	STEEL FRAME CA-50, DIAM. 6,3 (1/4) TO 12.5QSM (1/2) - SUPPLY / CUT (LOSS OF 10%) / FOLD / PLACEMENT	KG	4817	R$ 8,90	R$ 42.884,79
1.1.3	73942/002	Sinapi	STEEL FRAME CA-60 DIAM. 3,4 A 6.0 SQM-SUPPLY / CUT (WITH LOSS OF 10%) FOLD / PLACEMENT	KG	1711,36	R$ 8,77	R$ 15.006,57
1.1.4	74138/003	Sinapi	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.	M³	51,47	R$ 389,95	R$ 20.070,60
1.2			BEAMS				R$ 154.195,15
1.2.1	84216	Sinapi	FORMWORK FOR CONCRETE STRUCTURES (PILAR, BEAM AND SLAB) IN RESINED COMPENSATED WOODEN PLATE, OF 1,10X 2,20, THICKNESS = 12SQM, 05USES. (MANUFACTURE, ASSEMBLY AND DISASSEMBLY)	M²	1590,94	R$ 38,07	R$ 60.573,45
1.2.2	74254/002	Sinapi	STEEL FRAME CA-50, DIAM. 6,3 (1/4) TO 12.5SQM (1/2) - SUPPLY / CUT (LOSS OF 10%) / FOLD / PLACEMENT	KG	4854,1	R$ 8,90	R$ 43.215,08
1.2.3	73942/002	Sinapi	STEEL FRAME CA-60 DIAM. 3,4 A 6.0 SQM-SUPPLY / CUT (C / 10% LOSS) FOLD / PLACEMENT	KG	1349	R$ 8,77	R$ 11.829,11
1.2.4	74138/003	Sinapi	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.	M³	98,93	R$ 389,95	R$ 38.577,51
1.3			SLABS				R$ 183.986,15
1.3.1	74141/003	Sinapi	PRECAST SLAB BETA 16 P / 3,5KN / M2 SPAN 5,2M INCL JOISTS MATERIAL AND LABOR.	M²	1566,17	R$ 75,56	R$ 118.336,83
1.3.2	74254/002	Sinapi	STEEL FRAME CA-50, DIAM. 6.3 (1/4) TO 12.5 SQM (1/2) - SUPPLY / CUT (LOSS OF 10%) / FOLD / PLACEMENT	KG	270,3	R$ 8,90	R$ 2.406,43
1.3.3	73942/002	Sinapi	STEEL FRAME CA-60 DIAM. 3,4 A 6.0 SQM-SUPPLY / CUT (C / 10% LOSS) FOLD / PLACEMENT	KG	2322,8	R$ 8,77	R$ 20.368,17
1.3.4	74138/003	Sinapi	MACHINED CONCRETE PUMPED FCK = 25MPA, INCLUDING PLACING, SPREADING AND FINISHING.	M³	109,95	R$ 389,95	R$ 42.874,73
TOTAL							R$ 450.634,88

Source: Research data (2015)



Source: Research data (2015)

Figure 6. Quantitative comparative analysis



Source: Research data (2015)

Figure 7. Comparative analysis of total costs

and concrete were equivalent, being that the item precast slab does not appear in system of massive slabs, making the difference in costs not so dissimilar, as it is possible to analyze in Figure 7. Thus, it was concluded that for a four-story residential building, a structural system with massive slabs results in a cost of 2.8% greater than a structural system with prefabricated ribbed slabs with unidirectional lattice beams.

Final considerations

The factors that interfere with final cost of a venture are many, among them is the choice of structural system. This research was able to carry out cost analysis comparing two structural systems in a residential building with four floors, being analyzed structural systems in reinforced concrete using solid slabs and the other, using unidirectional prefabricated ribbed slabs with latticed beams, being able to be verified that structural analysis is of utmost importance in civil engineering and how this analysis can interfere with ultimate costs of an enterprise. The analysis in question showed that the difference between the two structural systems in relation to cost is of order of 2,8 %. The results of this research can be carried out for similar buildings, considering the number of floors, built area and type of use of building, and it is suggested that for larger buildings with more floors a new study should be done to analyze costs and verify the difference between two systems, so that it can be verified whether that difference tends to increase or decrease in case of buildings with a greater number of floors.

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